New Theme Course Submission Form

*Astronomy 2143: Cosmology – The History of the Universe*

*Submitted for approval for the new theme Origins and Evolution*

Background Statement

Astronomy 1143, Cosmology – The History of the Universe, has been taught as a Natural Sciences GE course since 2009. Traditionally, Astronomy has numbered all of its GE classes at 1000-level and used 2000-level and above for calculus-based courses designed for astronomy & astrophysics majors. Under the revised GE, we are numbering Foundation courses at 1000-level and renumbering the Theme courses to 2000-level. These courses, including Cosmology, have always required the application of algebra and geometry to understanding the physical universe and solving astrophysics problems. Our renumbering partly acknowledges that students have always regarded these courses as challenging, and it also recognizes the higher level of presentation, discussion, and assignments that are feasible now that students will have completed the Natural Sciences Foundation requirement before taking them.

As described in detail on the syllabus, Astronomy 2143 covers one of the most revolutionary transformations in modern science: the discovery that the earth occupies a “non-privileged” position in an expanding universe of enormous physical size and enormous but *finite* age, and that the dominant constituents of the cosmos are radically different from those we encounter in our everyday lives. These discoveries are based on Einstein’s theory of gravity and curved spacetime and on the physical understanding of light, atoms, and sub-atomic particles developed over the past 300 years. Cosmology addresses origins at the most fundamental of levels and explores evolution on the largest of spatial scales and the longest conceivable timescales.

The 3-credit hour course is comprised of class meetings involving lecture and small-group discussions, in-class questions based on those discussions, readings from the textbook *Your Cosmic Context* and from *The First Three Minutes* by Nobel Prize winning physicist Steven Weinberg, homework assignments that include reflection questions based on lectures and reading and multi-part calculational problems that guide students through key topics in cosmology, a concluding essay assignment in which students reflect on course themes, and a midterm and final exam that test mastery of course material. *The First Three Minutes* is one of the classics of popular science writing, an accessible but sophisticated account of the history of cosmology that is unusually good at demonstrating the often circuitous track of major scientific advances. *Your Cosmic Context* has an unusually broad perspective for a science textbook, covering topics clearly and accurately while also inviting students to make connections to their own experience and philosophical ideas. The in-class questions and homework assignments play central roles in achieving the ELOs and assessing that achievement. Examples of the multi-part questions from the homework assignments include: using data on variable stars to measure the distance to a nearby galaxy; building on this measurement and data on supernovae to measure the cosmic expansion rate (a.k.a. Hubble’s constant); demonstrating that Hubble’s linear expansion law is consistent with a homogeneous universe; inferring the amount of dark matter in a galaxy from measurements of its rotation speed; and using an observed map of the cosmic microwave background to infer the geometry of space. For in-class questions, students first work individually, then discuss their answers with a small group of peers before submitting them. Some of these are reflective, asking students to identify questions they have about cosmology or the results they find especially surprising, or to speculate on the spatial extent of the universe or the future duration of the cosmos and the human species. Some are review, helping students synthesize recently covered material and prepare for exams. Some are advanced, asking students to estimate the age of the universe from the value of the Hubble constant, to calculate a galaxy’s light-travel distance from the wavelengths of absorption lines in its spectrum, or to explain the relation between cosmic expansion and the temperature of the universe or the synthesis of helium in the big bang. The evidence for a hot, dense early universe, the estimation of the age of the universe from multiple lines of evidence, the evolution of structure in the cosmos, and expectations for the future of the universe are constant themes throughout the lectures, the readings, and the course assignments.

*In the remainder of this form, instructions and examples have been set in blue type while the new responses are set in black type.*

# Overview

Each category of the General Education (GE) has specific learning goals and Expected Learning outcomes that connect to the big picture goals of the program. Expected Learning Outcomes (ELOs) describe the knowledge or skills students should have by the end of the course. Courses in the GE Themes must meet the ELOs common for **all** GE Themes and those specific to the Theme, in addition to any ELOs the instructor has developed specific to that course.

The prompts below provide the goals of the GE Themes and seek information about which activities (discussions, readings, lectures, assignments) provide opportunities for students to achieve the ELO’s associated with that goal. The answer should be concise and use language accessible to colleagues outside of the submitting department or discipline. The specifics of the activities matter—listing “readings” without a reference to the topic of those readings will not allow the reviewers to understand how the ELO will be met. However, the panel evaluating the fit of the course to the Theme will review this form in conjunction with the syllabus, so if readings, lecture/discussion topics, or other specifics are provided on the syllabus, it is not necessary to reiterate them within this form.

# Goals and ELOs shared by *all* Themes

**Goal 1:** Successful students will analyze an important topic or idea at a more advanced and in-depth level than the foundations. In this context, “advanced” refers to courses that are e.g., synthetic, rely on research or cutting-edge findings, or deeply engage with the subject matter, among other possibilities.

**Goal 2:** Successful students will integrate approaches to the theme by making connections to out-of-classroom experiences with academic knowledge or across disciplines and/or to work they have done in previous classes and that they anticipate doing in future.

For each of the ELOs below, please identify and explain course assignments, readings, or other activities within this course that provide opportunity for students to attain the ELO. If the specific information is listed on the syllabus, it is appropriate to point to that document. The ELOs are expected to vary in their “coverage” in terms of number of activities or emphasis within the course. Examples from successful courses are shared on the next page.

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| **ELO 1.1 Engage in critical and logical thinking.** | As described in the syllabus and background statement, students will engage in logical thinking as they infer properties of galaxies and the cosmos using Newton’s and Einstein’s theories of gravity by applying physical intuition and mathematical reasoning, in lectures and small-group discussions and, especially, in answering in-class questions and homework problems.  Students will engage in critical thinking as they reflect on the theoretical and experimental advances that led to the modern understanding of cosmology, addressed in lectures, in small-group discussions and some in-class questions, in readings, and in reflection questions on homework assignments and the concluding essay. |
| **ELO 2.1 Identify, describe, and synthesize approaches or experiences.** | Astronomy 2143 shows how the detailed and empirically successful theory of contemporary cosmology emerges from Newtonian and Einsteinian gravity and the properties of atoms and electromagnetic radiation. In understanding and describing this edifice, students will build on the knowledge they have gained from the Natural Sciences foundation courses.  The story of modern cosmology involves an extraordinary, century-plus interplay between theoretical development and experimental or observational discoveries. Throughout the course students are challenged to identify these approaches, describe the interplay between them, and explain how the synthesis of theory and experiment leads to scientific advances. Students experience this challenge in lectures and reading, in in-class questions, and in homework assignments and exams. |
| **ELO 2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.** | At a concrete level, the development and progression of students in Astronomy 2143 is traced most clearly through the increasing sophistication of the multi-part problems in the homework assignments. For example, in the first assignment students use observations of Cepheid variable stars to infer the distance to a galaxy; in the second, they use distances of galaxies measured in this way to calibrate the luminosity of supernovae and use them to measure the cosmic expansion rate; in the third they use measured galaxy rotation speeds to infer the mass of the galaxy’s dark matter, then use inferred galaxy masses and the cosmic expansion rate to determine whether the expansion of the universe will continue forever; in the final assignment, they revisit these topics from a more sophisticated viewpoint, using observations of supernovae and the cosmic microwave background to demonstrate that we live in a universe with accelerating cosmic expansion and flat spatial geometry.  At a more abstract level, student reflection and self-assessment occurs through in-class, homework, and exam questions. For example, early in the course students are asked to speculate on whether the universe is finite or infinite in extent and in age and on whether the earth occupies a special location; they revisit these questions after learning more about modern cosmology. |

*Example responses (from Sociology 3200, Comm 2850, French 2803):*

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| ***ELO 1.1 Engage in critical and logical thinking.*** | *This course will build skills needed to engage in critical and logical thinking about immigration and immigration related policy through:*   * *Weekly reading response papers which require the students to synthesize and critically evaluate cutting-edge scholarship on immigration;* * *Engagement in class-based discussion and debates on immigration-related topics using evidence-based logical reasoning to evaluate policy positions;* * *Completion of an assignment which build skills in analyzing empirical data on immigration (Assignment #1)* * *Completion 3 assignments which build skills in connecting individual experiences with broader population-based patterns (Assignments #1, #2, #3)* * *Completion of 3 quizzes in which students demonstrate comprehension of the course readings and materials.* |
| ***ELO 2.1 Identify, describe, and synthesize approaches or experiences.*** | *Students engage in advanced exploration of each module topic through a combination of lectures, readings, and discussions.*  *Lecture*  *Course materials come from a variety of sources to help students engage in the relationship between media and citizenship at an advanced level. Each of the 12 modules has 3-4 lectures that contain information from both peer-reviewed and popular sources. Additionally, each module has at least one guest lecture from an expert in that topic to increase students’ access to people with expertise in a variety of areas.*  *Reading*  *The textbook for this course provides background information on each topic and corresponds to the lectures. Students also take some control over their own learning by choosing at least one peer-reviewed article and at least one newspaper article from outside the class materials to read and include in their weekly discussion posts.*  *Discussions*  *Students do weekly discussions and are given flexibility in their topic choices in order to allow them to take some control over their education. They are also asked to provide*  *information from sources they’ve found outside the lecture materials. In this way, they are able to*  *explore areas of particular interest to them and practice the skills they will need to gather information*  *about current events, analyze this information, and communicate it with others.*  *Activity Example: Civility impacts citizenship behaviors in many ways. Students are asked to choose a TED talk from a provided list (or choose another speech of their interest) and summarize and evaluate what it says about the relationship between civility and citizenship. Examples of Ted Talks on the list include Steven Petrow on the difference between being polite and being civil, Chimamanda Ngozi Adichie’s talk on how a single story can perpetuate stereotypes, and Claire Wardle’s talk on how diversity can enhance citizenship.* |
| **ELO 2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.** | *Students will conduct research on a specific event or site in Paris not already discussed in depth in class. Students will submit a 300-word abstract of their topic and a bibliography of at least five reputable academic and mainstream sources. At the end of the semester they will submit a 5-page research paper and present their findings in a 10-minute oral and visual presentation in a small-group setting in Zoom.*  *Some examples of events and sites:*   * *The Paris Commune, an 1871 socialist uprising violently squelched by conservative forces* * *Jazz-Age Montmartre, where a small community of African-Americans–including actress and singer Josephine Baker, who was just inducted into the French Pantheon–settled and worked after World War I.* * *The Vélodrome d’hiver Roundup, 16-17 July 1942, when 13,000 Jews were rounded up by Paris police before being sent to concentration camps* * *The Marais, a vibrant Paris neighborhood inhabited over the centuries by aristocrats, then Jews, then the LGBTQ+ community, among other groups.* |

# Goals and ELOs of the GE Theme: Number, Nature, and Mind

**GOAL 1:** 1. Successful students will analyze the origins and evolution of natural systems, life, humanity, or human culture at a more advanced and in-depth level than in the Foundations component.

**GOAL 2:** Successful students will integrate approaches to the origins and evolution of natural systems, life, humanity, or human culture by making connections to their own experiences and by making connections to work they have done in previous classes and/or anticipate doing in the future.

**GOAL 3:** Successful students will appreciate the time depth of the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

**GOAL 4:** Successful students will understand the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

Enter your ELOs in the Table below, editing and removing rows as needed. There should be at least one ELO for each goal, and they should be numbered to correspond to the goal (e.g., ELO1.1 is the first ELO for Goal 1, ELO 2.2 would be the second ELO for the second goal).

For each ELOs, please identify and explain course assignments, readings, or other activities within this course that provide opportunity for students to attain the ELO. If the specific information is listed on the syllabus, it is appropriate to point to that document. The number of activities or emphasis within the course are expected to vary among ELOs. Examples from successful courses are shared below.

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| **ELO 1.1**  Apply their understanding of scientific methods to quantitative calculations. | Lectures and textbook readings will teach students how a scientific idea can be expressed in equations, the equations can be used to draw new conclusions, and the conclusions can be tested against empirical data. They will experience this process directly in homework assignments, in-class questions, and exams. For example, in an early homework assignment students will demonstrate that if a linear velocity-distance relation (a.k.a. Hubble’s law) is seen by one observer in a homogeneous universe then it will be seen by all observers regardless of location. In a late assignment, students will deduce the geometry of space from the size of spots in a map of the cosmic microwave background. |
| **ELO 1.2**  Engage in critical and logical thinking about the origins and evolution of the universe, physical systems, life on earth, humanity, or human culture. | As described in the syllabus and background statement, students will engage in critical and logical thinking about the origins and evolution of the universe as they explore the evidence for an expanding universe, the big bang theory, dark matter, and dark energy in lectures and small-group discussions and, especially, in answering in-class questions and homework problems. For example, in one homework assignment students will use their knowledge of gravity and measurements of galaxy rotation to deduce the existence of a dark matter halo surrounding the galaxy. In lecture, readings, and other assignments they will learn about multiple lines of evidence for dark matter, discuss alternative hypotheses, and learn about the experiments being conducted to try to discover the particle nature of dark matter. |
| **ELO 2.1**  Identify, describe, and synthesize approaches to or experiences of origins and evolution questions in different academic and non-academic contexts. | The story of cosmology involves an extraordinary, century-plus interplay between theoretical development and experimental or observational discoveries. Throughout the course students are challenged to identify these approaches, describe the interplay between them, and explain how the synthesis of theory and experiment leads to scientific advances. Students experience this challenge in lectures and reading, in in-class questions, and in homework assignments and exams.  I  The scientific approach to understanding the origin and evolution of the cosmos is the core of Astron 2143. It seems initially paradoxical that we can study these topics from our vantage point in the present day. Students learn how the finite speed of light makes telescopes work as “time machines” that observe galaxies in the distant past, and they learn how “fossil” evidence such as the cosmic abundance of helium and deuterium can tell us about physics in the infant universe. At various points in the course they are invited to compare the age of the universe to solar system and human timescales. |
| **ELO 2.2**  Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts. | At a concrete level, the development and progression of students in Astronomy 2143 is traced most clearly through the increasing sophistication of the multi-part problems in the homework assignments. For example, in the first assignment students use observations of Cepheid variable stars to infer the distance to a galaxy; in the second, they use distances of galaxies measured in this way to calibrate the luminosity of supernovae and use them to measure the cosmic expansion rate; in the third they use measured galaxy rotation speeds to infer the mass of the galaxy’s dark matter, then use inferred galaxy masses and the cosmic expansion rate to determine whether the expansion of the universe will continue forever; in the final assignment, they revisit these topics from a more sophisticated viewpoint, using observations of supernovae and the cosmic microwave background to demonstrate that we live in a universe with accelerating cosmic expansion and flat spatial geometry.  At a more abstract level, student reflection and self-assessment occurs through in-class, homework, and exam questions. For example, early in the course students are asked to speculate on whether the universe is finite or infinite in extent and in age and on whether the earth occupies a special location; they revisit these questions after learning more about modern cosmology. |
| **ELO 3.1**  Illustrate the time depth of the universe, physical systems, life on earth, humanity, or human culture by providing examples or models. | The 14 billion year age of the universe is a touchstone throughout the course. In homework assignments, students use measurements of variable stars and supernovae to determine the cosmic expansion rate and from it infer the age of the universe, building on the understanding that they develop from lectures and readings. They learn why the cosmological model based on Einstein’s General Relativity predicts a “big bang” beginning of the universe, and thus a finite age. They learn how the amount of dark matter and dark energy in the universe affect its age and its eventual fate. They examine current evidence that the *future* duration of the universe will be infinite even though its past is finite, and the uncertainties in this empirically based theoretical prediction. |
| **ELO 3.2** Explain scientific methods used to reconstruct the history of the universe, physical systems, life on earth, humanity, or human culture and specify their domains of validity. | Students learn how astronomers and physicists are able to reconstruct the history of the universe even back to its first second using observations and physical principles. As explained in the lectures and readings, this reconstruction relies on the assumption that the underlying mechanisms of physics are the same throughout space and time, even though their manifestations may be different; students also learn about the kinds of observations that support this assumption. For example, students trace the extraordinary chain of theory and experiment that allow us to use measurements of atomic nuclei in terrestrial laboratories today to predict the amount of deuterium formed in the first three minutes after the big bang and to confirm this prediction using measurements of gas in galaxies that are billions of light years away. Students’ understanding of these methods is deepened and assessed through in-class questions, homework problems, and exam questions. |
| **ELO 3.3** Engage with current controversies and problems related to origins and evolution questions. | The vast gap between the age of the universe and the timescales of human history remains a controversial topic in American culture. In Astronomy 2143 students learn the scientific evidence for the big bang origin of the universe and its14 billion year present-day age. At the end of the course students often comment that this evidence is much, much stronger and more compelling than they realized before taking the class. The class does not force discussion of scientific vs. religious perspectives on origins and evolution, but at several points in the course students have the option to address this tension if they wish to do so, for example in response to homework assignment questions such as “Does the finite, 14 billion year age of the universe surprise you?” or “How long do you expect the human species to last and why?” |
| **ELO 4.1** Describe how the universe, physical systems, life on earth, humanity, or human culture have evolved over time. | Astronomy 2143 concentrates on the empirically well established evolution of the universe from the age of about 1 second to the present day, while also discussing more uncertain ideas about cosmic evolution between the Planck time (10-43 seconds) and 1 second and from the present day into the possibly infinite future. This evolutionary history is a constant theme of the lectures and readings, and students explore it further through in-class questions and homework assignments. |
| **ELO 4.2** Summarize current theories of the origin and evolution of the universe, physical systems, life on earth, humanity, or human culture. | The big bang theory is one of the great achievements of human culture. Based on Einstein’s mathematical description of curved spacetime and gravity and simple assumptions about the homogeneity of the universe, the theory at first seemed highly speculative. Over many decades of empirical discovery and further theoretical development, it became one of the most thoroughly tested theories of modern science. In Astronomy 2143, students learn this scientific history in detail, and they learn key aspects of the “extended big bang theory” that draws on cosmic inflation, dark matter, and dark energy to explain the formation and evolution of galaxies and large-scale cosmic structure. They summarize elements of these theories throughout the course, in in-class questions, homework assignments, and exams. The concluding essay invites students to present a course-long overview of what they have learned, about the origin and evolution of the universe and about the theoretical and observational developments that have established our contemporary understanding of this subject. |

*Example responses (from History/Religious Studies 3680, Music 3364; Sociology 3200) for the “Citizenship” Theme:*

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| ***ELO 1.1 Describe and analyze a range of perspectives on what constitutes citizenship and how it differs across political, cultural, national, global, and/or historical communities.*** | *Citizenship could not be more central to a topic such as immigration/migration. As such, the course content, goals, and expected learning outcomes are all, almost by definition, engaged with a range of perspectives on local, national, and global citizenship. Throughout the class students will be required to engage with questions about what constitutes citizenship and how it differs across contexts.*  *The course content addresses citizenship questions at the global (see weeks #3 and #15 on refugees and open border debates), national (see weeks #5, 7-#14 on the U.S. case), and the local level (see week #6 on Columbus). Specific activities addressing different perspectives on citizenship include Assignment #1, where students produce a demographic profile of a U.S-based immigrant group, including a profile of their citizenship statuses using U.S.-based regulatory definitions. In addition, Assignment #3, which has students connect their family origins to broader population-level immigration patterns, necessitates a discussion of citizenship. Finally, the critical reading responses have the students engage the literature on different perspectives of citizenship and reflect on what constitutes citizenship and how it varies across communities.* |
| ***ELO 1.2 Identify, reflect on, and apply the knowledge, skills and dispositions required for intercultural competence as a global citizen****.* | *This course supports the cultivation of "intercultural competence as a global citizen" through rigorous and sustained study of multiple forms of musical-political agency worldwide, from the grass-roots to the state-sponsored. Students identify varied cultural expressions of "musical citizenship" each week, through their reading and listening assignments, and reflect on them via online and in-class discussion. It is common for us to ask probing and programmatic questions about the musical-political subjects and cultures we study. What are the possibilities and constraints of this particular version of musical citizenship? What might we carry forward in our own lives and labors as musical citizens Further, students are encouraged to apply their emergent intercultural competencies as global, musical citizens in their midterm report and final project, in which weekly course topics inform student-led research and creative projects.* |
| ***ELO 2.1 Examine, critique, and evaluate various expressions and implications of diversity, equity, inclusion, and explore a variety of lived experiences.*** | *Through the historical and contemporary case studies students examine in HIST/RS 3680, they have numerous opportunities to examine, critique, and evaluate various expressions and implications of diversity, equity, and inclusion, as well as a variety of lived experiences. The cases highlight the challenges of living in religiously diverse societies, examining a range of issues and their implications. They also consider the intersections of religious difference with other categories of difference, including race and gender. For example, during the unit on US religious freedom, students consider how incarcerated Black Americans and Native Americans have experienced questions of freedom and equality in dramatically different ways than white Protestants. In a weekly reflection post, they address this question directly. In the unit on marriage and sexuality, they consider different ways that different social groups have experienced the regulation of marriage in Israel and Malaysia in ways that do not correspond simplistically to gender (e.g. different women's groups with very different perspectives on the issues).*  *In their weekly reflection posts and other written assignments, students are invited to analyze the implications of different regulatory models for questions of diversity, equity, and inclusion. They do so not in a simplistic sense of assessing which model is "right" or "best" but in considering how different possible outcomes might shape the concrete lived experience of different social groups in different ways. The goal is not to determine which way of doing things is best, but to understand why different societies manage these questions in different ways and how their various expressions might lead to different outcomes in terms of diversity and inclusion. They also consider how the different social and demographic conditions of different societies shape their approaches (e.g. a historic Catholic majority in France committed to laicite confronting a growing Muslim minority, or how pluralism \*within\* Israeli Judaism led to a fragile and contested status quo arrangement). Again, these goals are met most directly through weekly reflection posts and students' final projects, including one prompt that invites students to consider Israel's status quo arrangement from the perspective of different social groups, including liberal feminists, Orthodox and Reform religious leaders, LGBTQ communities, interfaith couples, and others.* |
| ***ELO 2.2 Analyze and critique the intersection of concepts of justice, difference, citizenship, and how these interact with cultural traditions, structures of power and/or advocacy for social change.*** | *As students analyze specific case studies in HIST/RS 3680, they assess law's role in and capacity for enacting justice, managing difference, and constructing citizenship. This goal is met through lectures, course readings, discussion, and written assignments. For example, the unit on indigenous sovereignty and sacred space invites students to consider why liberal systems of law have rarely accommodated indigenous land claims and what this says about indigenous citizenship and justice. They also study examples of indigenous activism and resistance around these issues. At the conclusion of the unit, the neighborhood exploration assignment specifically asks students to take note of whether and how indigenous land claims are marked or acknowledged in the spaces they explore and what they learn from this about citizenship, difference, belonging, and power. In the unit on legal pluralism, marriage, and the law, students study the personal law systems in Israel and Malaysia. They consider the structures of power that privilege certain kinds of communities and identities and also encounter groups advocating for social change. In their final projects, students apply the insights they've gained to particular case studies. As they analyze their selected case studies, they are required to discuss how the cases reveal the different ways justice, difference, and citizenship intersect and how they are shaped by cultural traditions and structures of power in particular social contexts. They present their conclusions in an oral group presentation and in an individually written final paper. Finally, in their end of semester letter to professor, they reflect on how they issues might shape their own advocacy for social change in the future.* |